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CHAPTER 6: MAINSTREAM HABITAT QUALITY

INTRODUCTION

The carrying capacity of upper trophic levels in riverine environments is, to a large degree, dependent upon the biomass and productivity of food organisms. This trophic structure in the San Juan River was defined prior to and after spring runoff during 1994, 1995, and 1996. The overall objective of this investigation was to:

> ***Evaluate temporal and longitudinal distribution of physical and biological components of the benthic community associated with riffle and run habitats in the San Juan River.***

The river continuum concept (Vannote et al. 1980) was central to the formulation and fulfillment of the above objective. This concept proposes that the structure and function of river communities are in direct response to physical conditions within the river which change from the headwaters to the mouth. It contends that the biological community responds predictably to physical habitat characteristics which are largely regulated by fluvial geomorphic processes. To assess changes in the biological community in response to different hydrographics requires an understanding of the interrelationships between the physical and biological environment.

The major objective of the San Juan Recovery Implementation Program is to recovery the threatened and endangered Colorado pikeminnow and razorback sucker. An understanding of the dynamics of the primary and secondary trophic levels within the San Juan River are critical in this process. The carrying capacity of these two rare fishes, as well as the remaining native fish community, will be in part determined by the primary and secondary trophic levels.

METHODS

This investigation was undertaken in the San Juan River (Figure 1.1) from the tailwater of Navajo Reservoir to the confluence of the San Juan River with Lake Powell. This portion of the San Juan River was sampled based upon previously defined geomorphic reaches. Table 6.1 summarizes the number of riffle and run habitats sampled by date and location. Over the duration of the study, Reaches 2 through 7 were sampled between 13 and 18 times, with Reach 1 being sampled only once and Reach 8 sampled eight times. As stated previously, sample dates corresponded to before and after runoff in 1994, 1995, and 1996.

Sample methods and protocols were the same as those employed by Lamarra (1999) and are summarized below.

Measurements to evaluate primary and secondary trophic levels were collected from replicate riffle and run habitats selected randomly from each geomorphic reach. At each site, samples were collected

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from three locations parallel to the shore at approximately 1 to 1.5 feet water depth within these two habitats. These samples were collected from locations that were similar in depth, velocity and substrate within each sample reach and habitat to aid in a longitudinal comparison.

Physical Parameters

Physical parameters (Table 6.2) collected within each sample reach were assumed to have the greatest influence on primary and secondary trophic levels based upon literature data. Most parameters were collected at each sample location parallel to the shoreline.

Table 6.1. A Summary of the Number of Riffle and Run Habitats Sampled by Date and Geomorphic Reach in the San Juan River.

	GEOMORPHIC REACH																
	1		2		3		4		5		6		7		8		TOTAL
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	
APR. 94	1	1	2	0	3	3	2	2	2	2	2	2	3	3	1	1	29
NOV.94	0	0	3	3	3	3	2	2	3	3	2	2	3	3	1	1	34
APR. 95	0	0	3	3	3	3	3	3	4	4	3	3	5	5	2	2	46
FEB. 96	0	0	5	5	3	3	3	3	3	3	4	4	3	3	2	2	46
SEP. 96	0	0	5	5	3	3	3	3	3	3	3	3	3	3	2	2	44
TOTAL	**1**	**1**	**18**	**18**	**15**	**15**	**13**	**13**	**15**	**15**	**14**	**14**	**17**	**17**	**8**	**8**	**202**

A=Riffle; B=Run

Table 6.2. Physical and Biological Parameters Collected Within Each Sample Reach for Selected Run and Riffle.

WITHIN SAMPLE LOCATION	UNIT
Physical	
Water depth	meters
Bottom and average column water velocity	ft/sec
Dominant substrate size	D_{16}, D_{50}, D_{84}
Interstitial substrate size fractions	mm
Depth to embeddedness	mm
Percent surface area embedded	%
Interstitial void volume	cm^3/m^2
Biological	
periphyton biomass	mg/m^2
macroinvertebrate biomass	gm/m^2
coarse particulate organic matter	gm/m^2
fine particulate organic matter	% loss on ignition

Water column depth, bottom velocity and mean column velocity (0.6 depth) were collected at each sample location. Depth was measured with a stadia rod and velocities with a Marsh-McBirney current meter.

The percent of cover of the two dominant substrate size fractions were estimated at sample locations. Wolman pebble counts (Wolman 1954) were also conducted within the vicinity of the three samples parallel to the shoreline to quantify the size distribution of substrates in these regions. The percent embeddedness of large substrates at each sampling point was estimated from the portion of the substrate exposed above interstitial sediments. Depth to embeddedness was measured as the distance from the top of large substrates to the upper boundary of interstitial sediments. Interstitial substrates were collected at each sample location with a core tube. These samples were dried in the laboratory and separated into size fractions. The percent organic composition of the smallest sediment size fraction (<2 mm) was measured and used as an estimate of fine particulate organic matter (FPOM).

Biological Parameters

Biological parameters collected at each sample location included periphyton biomass, benthic detritus, and biomass of benthic macroinvertebrates. Periphyton was quantitatively collected from cobble-sized rocks. Chlorophyll-*a* content of these samples was used as a measure of periphyton biomass and was measured in the laboratory with a spectrophotometer. Benthic macroinvertebrates were collected at each sample location with a Hess sampler. Samples were preserved in alcohol and analyzed in the laboratory. Organic material from these samples was dried and weighed to provide estimates of detritus coarse particulate organic matter (CPOM).

RESULTS

Between 1994 and 1996, the trophic structure of the San Juan River was quantitatively described during five time periods. The experimental design required sample periods to be before and after spring runoff during baseflow conditions. Because the San Juan basin is subject to summer and fall monsoons, baseflows during the three study years varied greatly. Table 6.3 summarizes the hydrologic conditions of the spring runoff period as well as the subsequent summer/fall baseflow period. As can be seen from this table, each year was significantly different relative to the magnitude of the runoff hydrograph, as well as the summer baseflow period. Figure 6.1 shows the times of the five sample periods relative to the flows in the San Juan River.

The lowest magnitude runoff year was 1996 which also contained the most storm events (12) post runoff. The 1994 hydrograph was intermediate in both magnitude and the number of storm events (9), however, the amount of runoff was considered above average for the post dam period (1962-current). The highest magnitude runoff (1995) during the habitat quality period, also had the lowest (5) number of post runoff monsoon summer storms. As noted in Table 6.3, a number of physical and biological parameters were measured during the course of this investigation. The sample design (Table 6.2) provided data from various reaches of the San Juan River during three runoff cycles. Results are first summarized temporally, followed by a spatial analysis. In each analysis, the data is

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Table 6.3. A Summary of the 1994, 1995, and 1996 Runoff Hydrograph and Subsequent Monsoon Periods Prior to Each Sample Date (Data from Four-Corners, NM).

	1994	1995	1996
Peak Runoff (cfs)	10,000	12,100	3,540
Days > 10,000	0	11	0
Days > 8,000	13	27	0
Days > 5,000	49	72	0
Days > 2,500	67	135	36
Storms [a]	9	5	12

[a] Summer/Fall storms after runoff but prior to the specified sample date.
1994 - November 15, 1994; 1995 - February 21, 1996; 1996 - September 20, 1996

evaluated on a river-wide basis as well as by habitat type (run or riffle). To determine significant differences by sample date, reach or habitat types, for the parameters measured in this study, a one-way ANOVA was preformed. A post ANOVA Tukeys HSD (%=.05) was used to determine which types, reaches, or habitats were significantly different from other factors. The complete statistical results can be seen in Appendix C.

Temporal Variations

Physical Parameters

The major physical parameters measured at each sample location involved the quantitative description of streambed materials. The three physical parameters measured characterized the bed structure. Wolman pebble counts, in combination with bed size fractions of materials less than 2 cms, quantitatively determined the size distribution of bed materials. The second physical parameter, depth to embeddedness (DTE), is a measure of the distance from the top of the substrate to the top of the layer of fines in which the substrate is embedded. It represents an index of the available interstitial depth for aquatic organisms. The third parameter, the percent of surface area embedded (PAE), is a measure of the two-dimensional surface area (% surface area), covered by fine material.

The substrate size is expressed by three calculated values D_{16}, D_{50}, and D_{84}. The overall average values for each trip, as well as the 95% confidence intervals, can be seen in Figure 6.2. In each case, the one way ANOVA indicated that significant differences were found between trips for all habitats combined. For the D_{84} and D_{50} values, the April 1995 trip was found to be significantly different from all other trips. For D_{16}, no significant differences were found. A comparison of the same three calculated values by habitat type also showed significant differences not only by trip but also between habitat type (Figure 6.2). On each sample date (with the exception of April 1994), riffles had significantly larger substrate size compared to run habitats. Although no significant differences were found for D_{50} values in riffle habitats by date, runs did demonstrate significant difference.

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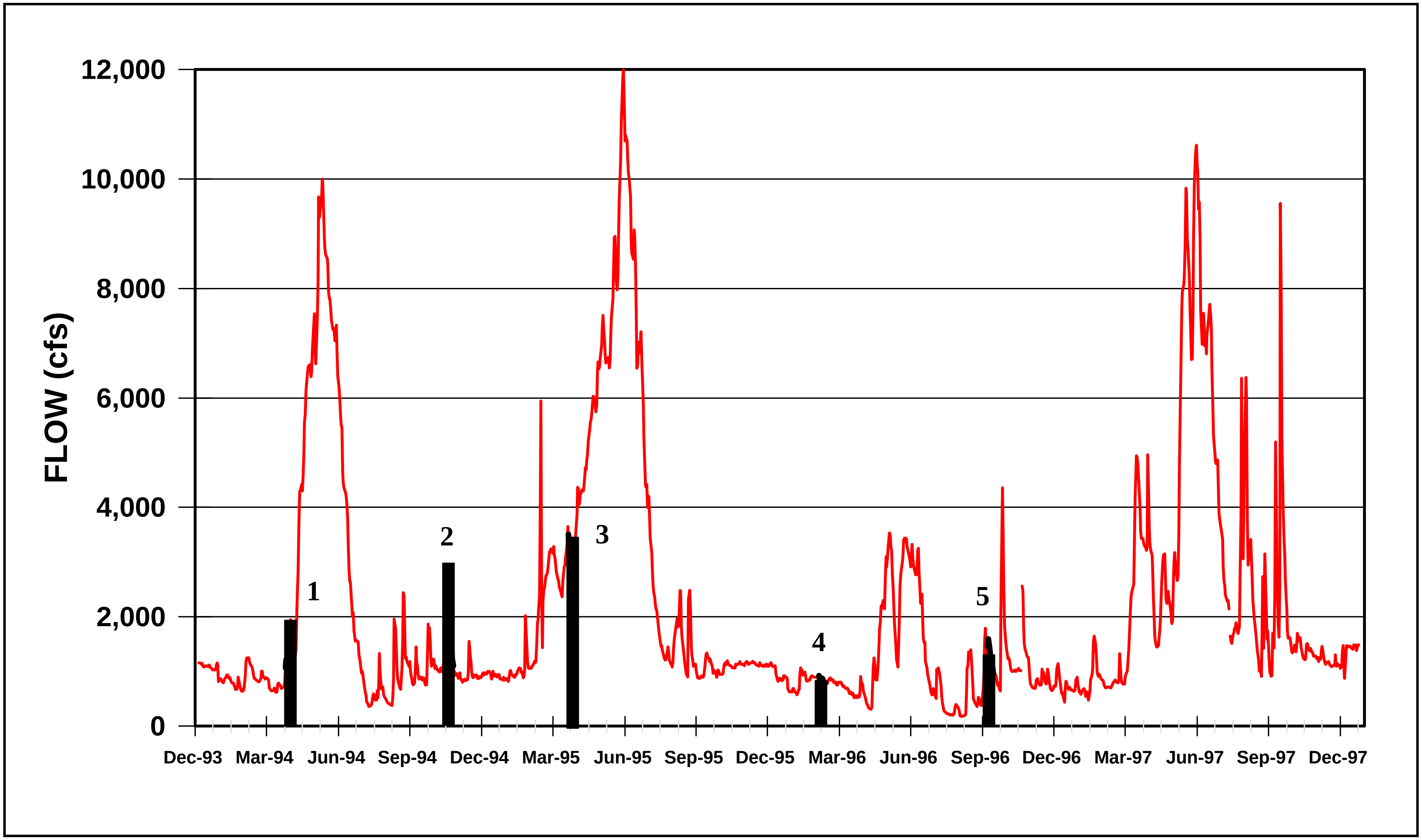

Figure 6.1 **The 1994 to 1997 Hydrograph at Four Corners, NM for the San Juan River. Habitat Quality Sample Periods Are Shown as Dark Columns on the Hydrograph**

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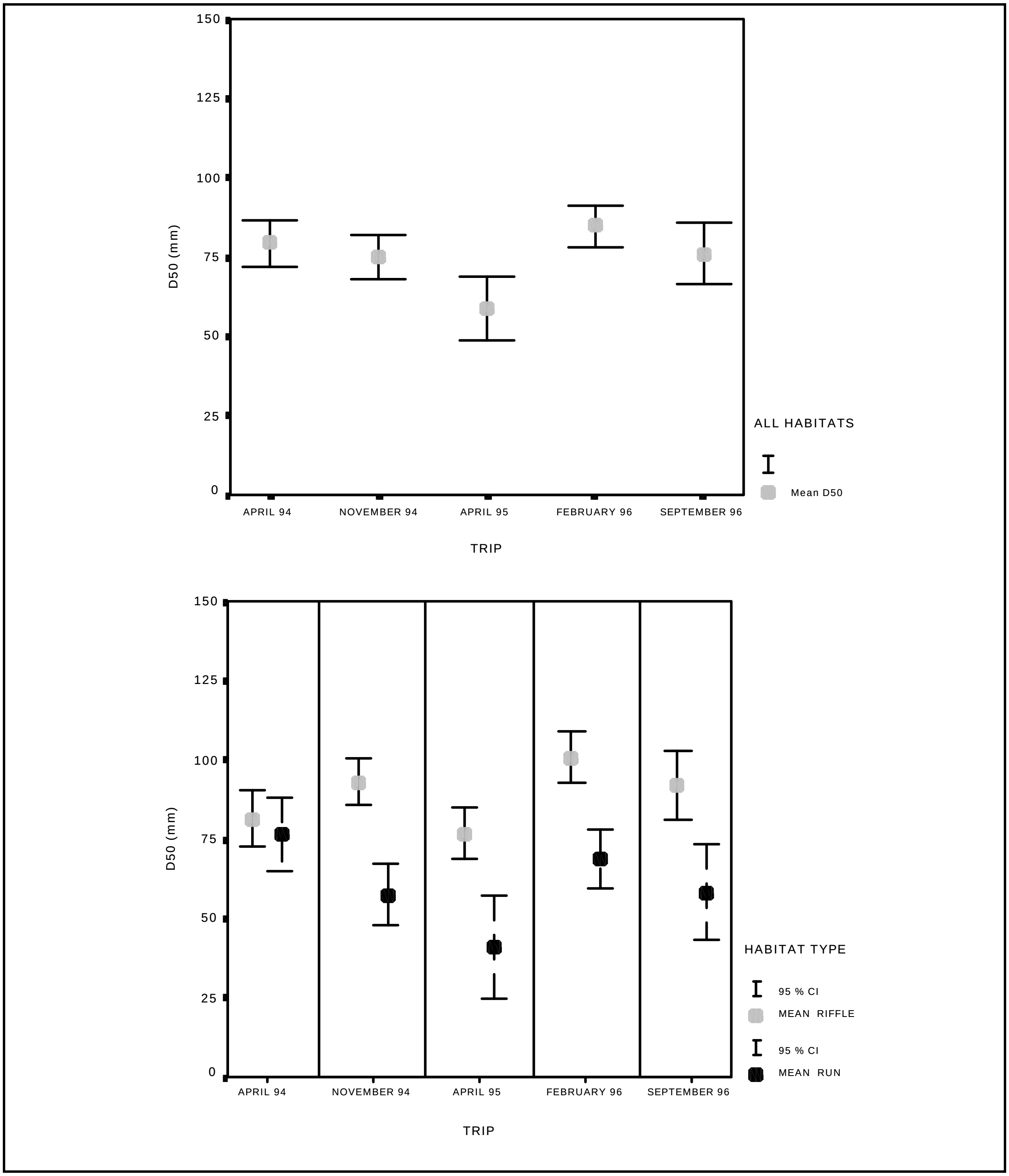

Figure 6.2 **The Temporal Distribution of the Substrate D_{50} Values for Each Trip Date for All Habitats Combined (above) and for Each Habitat Type (below) for the San Juan River**

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Comparisons of the depth to embedded layer (DTE) for riffles and runs can be seen in Figure 6.3. For all habitats combined, the February 1996 trip was significantly less than all other trips. This sample date had the longest time period between the end of runoff and the sample date. In four of the five sample dates, riffles had deeper depth to embedded layer when compared to runs. As stated previously, the shallowest depth to embedded layer for both habitats occurred in February 1996.

The percent surface area embedded (PAE) represents a measure of the sand or silt covering the dominant substrate type. As can be seen in Figure 6.4, significant differences occurred between dates for all habitats combined and for separate habitats. For all habitats combined, no differences were found for April 1994 compared to the other dates, while November 1994, April 1995 and September 1996 were found to be significantly different from other trips. In addition, inspection of Figure 6.4 indicates that run habitats had significantly greater surface areas embedded when compared to riffle habitats for all five samples. Runs averaged between 32.5% and 56.9% surface area embedded while riffles averaged only 14% to 26.6%.

Biological Parameters

In order to define the trophic structure of the San Juan River, primary and secondary producers were quantified in the same locations where physical parameters were measured.

Primary producers were quantified by determining the *in-situ* standing crop of periphyton (gm/m^2) and the concentration of benthic detritus (gm/m^2) associated with the substrate. Periphyton biomass expressed as a river-wide mean concentration was significantly different for both the April 1994 and November 1994 sample dates compared to the other sample periods (Figure 6.5). April 1995, February 1996, and September 1996 were not significantly different from each other. River-wide maximum biomass levels of periphyton occurred in April 1994 (6.4 gm/m^2) and river-wide minimum concentrations occurred in September 1996 (1.9 gm/m^2). The comparison of periphyton biomass by habitat type demonstrates the same temporal pattern for each habitat type with no significant differences between habitats. The same significant differences by date noted in the river-wide comparisons was also found for the two habitat types (riffle and run).

The concentration of coarse particulate organic material (detritus) in the substrates of the San Juan River were found to differ by sample date. The September 1996 sample period had significantly greater (65.2 gm/m^2) biomass compared to the February 1996 and April 1995 samples. The April 1995 detritus levels were the lowest (21.7 gm/m^2) of any sample date. The April 1994 and November 1994 detritus concentrations were not found to be significantly different from February or September 1996.

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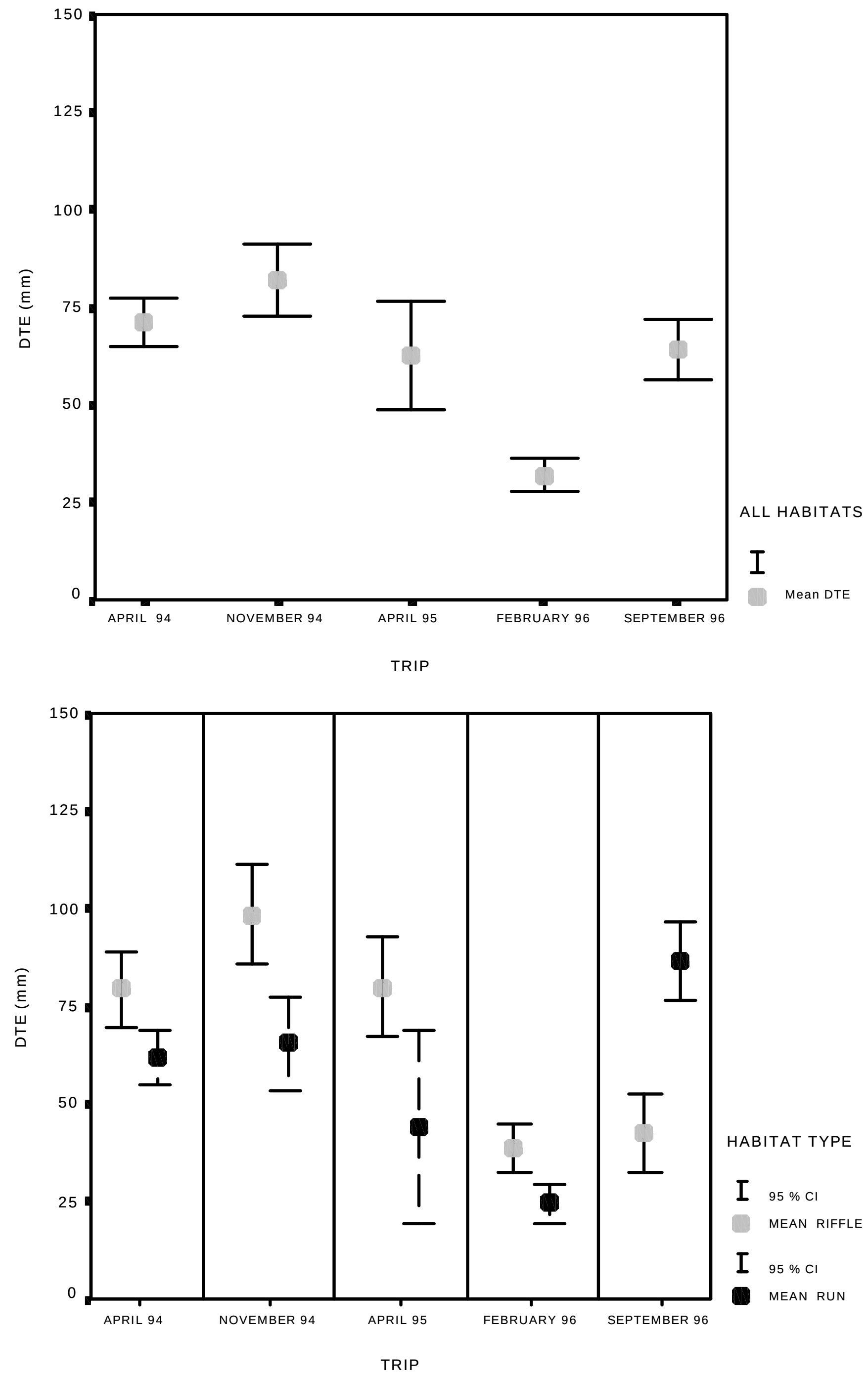

Figure 6.3 The Temporal Distribution of the Depth of Embedded Layer (DTE) for Each Trip Date for All Habitats Combined (above) and for Each Habitat Type (below) for the San Juan River

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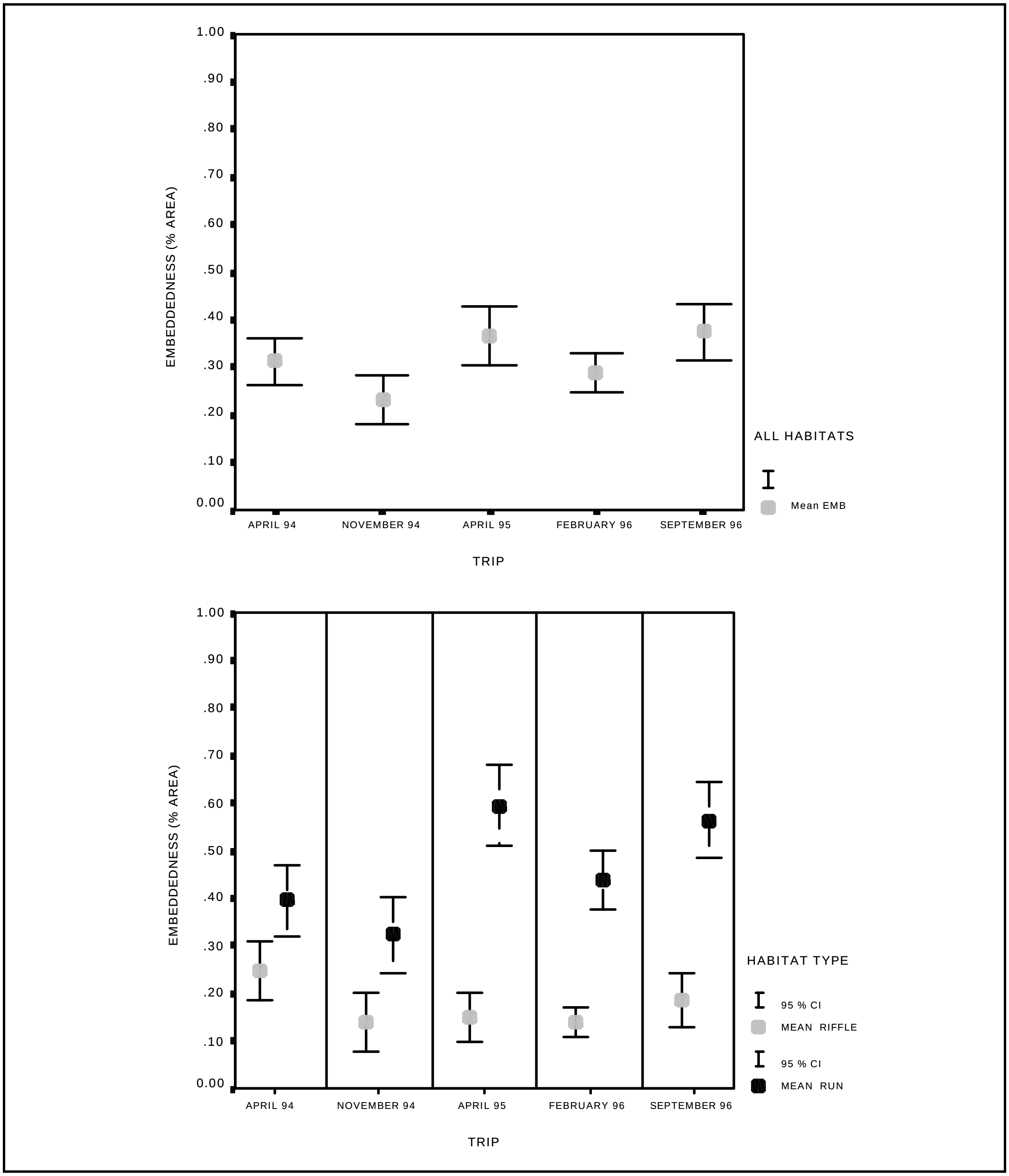

Figure 6.4 **The Temporal Distribution of the Percent Surface Area Embedded (PAE) for Each Trip Date for All Habitats Combined (above) and for Each Habitat Type (below) for the San Juan River**

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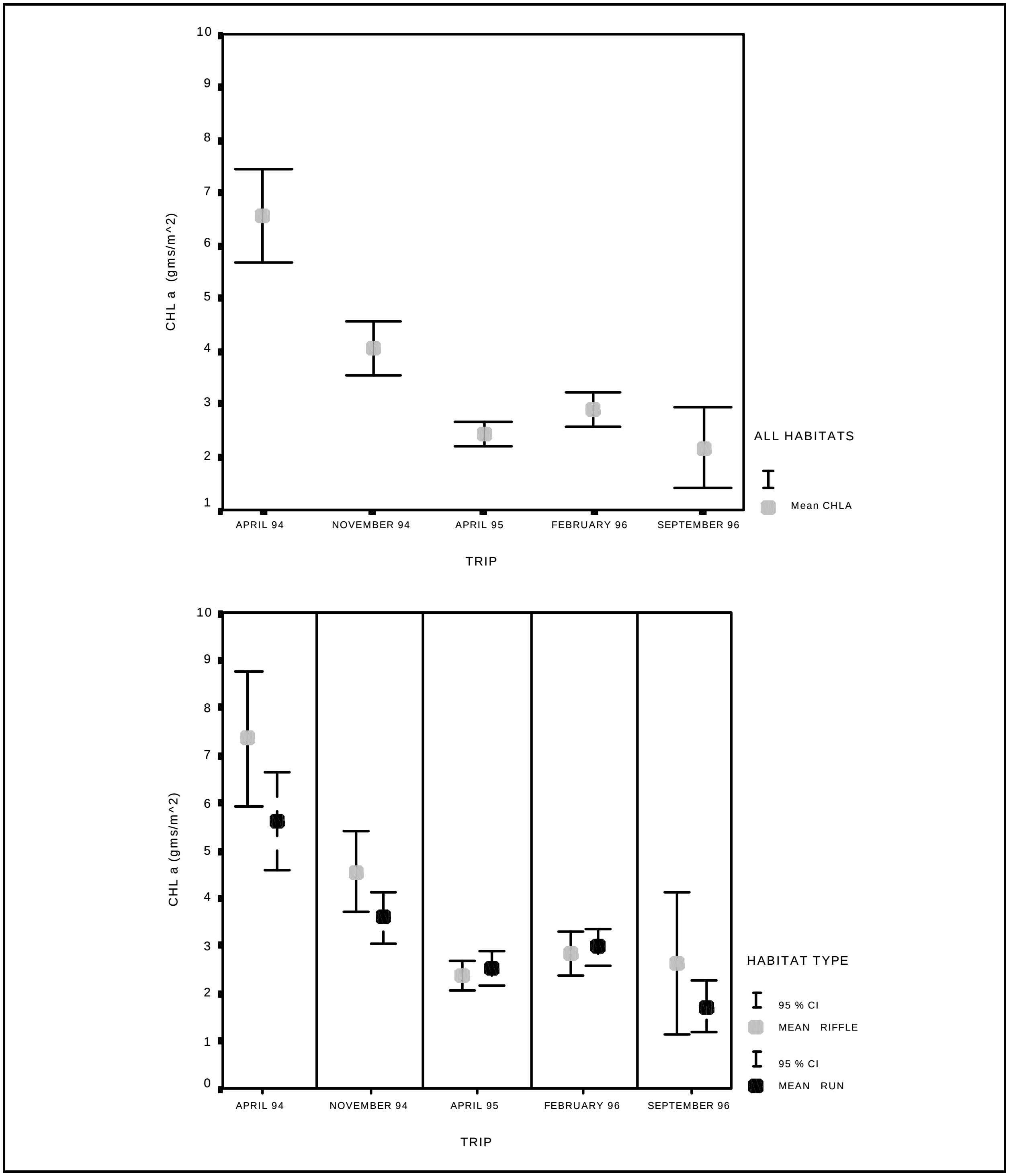

Figure 6.5 **The Temporal Distribution of the Biomass of Periphyton (gms chla/m^2) for Each Trip Date for All Habitats Combined (above) and for Each Habitat Type (below) for the San Juan River**

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The concentration of detritus within habitats was also found to be significantly different by sample date. The pattern found was the same for each habitat and followed the river-wide mean concentrations. The comparison between habitats (Figure 6.6 lower graph) indicated that there was no difference between habitats for April and November 1994 but significant differences (riffles greater than runs) for April 1995, February 1996, and September 1996. The largest difference occurred in September 1996 with riffles having an average density of 99.8 gm/m^2 and runs only 30.9 gm/m^2.

Biomass of secondary producers was determined by quantitatively sampling the benthic macroinvertebrate community. The river-wide mean invertebrate dry weights (gm/m^2) for the San Juan River are presented in Figure 6.7. There were significant differences in the San Juan River by sample period. The highest invertebrate biomass estimates were found in April 1994 (5.5 gm/m^2) and February 1996 (5.25 gm/m^2). The lowest levels were found in September 1996 (0.74 gm/m^2). Significant differences between riffles and runs were found in four of the five sample dates with riffles having higher invertebrate biomass levels.

Because of the combination of runoff hydrograph characteristics and the post runoff storm events prior to fall sampling, it is difficult to separate the effects of different runoff characteristics. Post runoff storm events and their associated sediment loading may deteriorate or enhance the effects of a particular runoff pattern. Table 6.4 summarizes the response of the measured parameters pre- and post runoff for three years (1994, 1995, and 1996). Of the 48 pair-wise comparisons, fifteen (31%) were found to be significantly different. Most notable was the biological response to a low flow/high storm sequence which negatively decreased periphyton and invertebrates and positively increased detritus concentrations in both riffles and runs.

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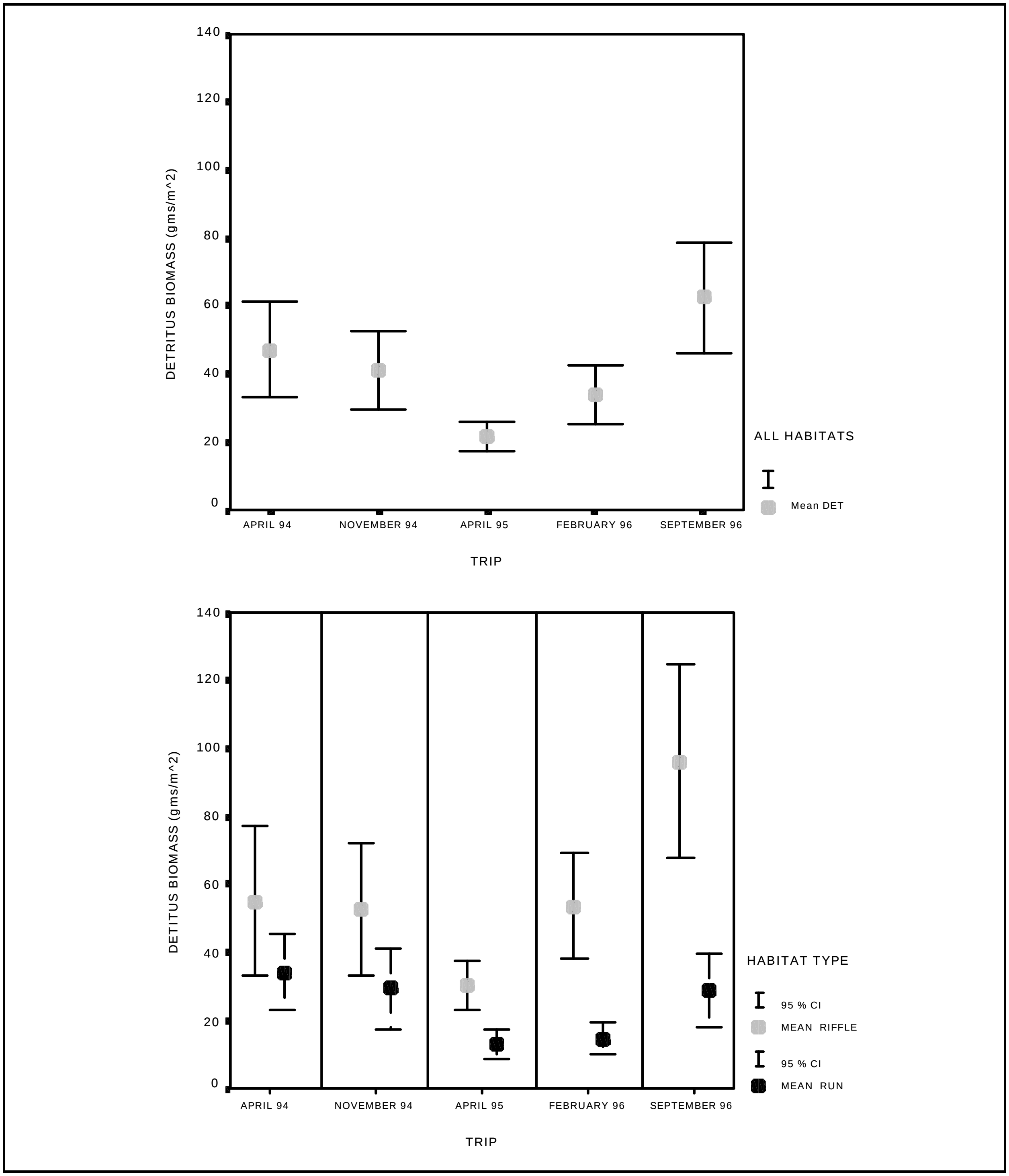

Figure 6.6 The Temporal Distribution of the Benthic Detritus (gms cpom/ m^2) for Each Trip Date for All Habitats Combined (above) and for Each Habitat Type (below) for the San Juan River

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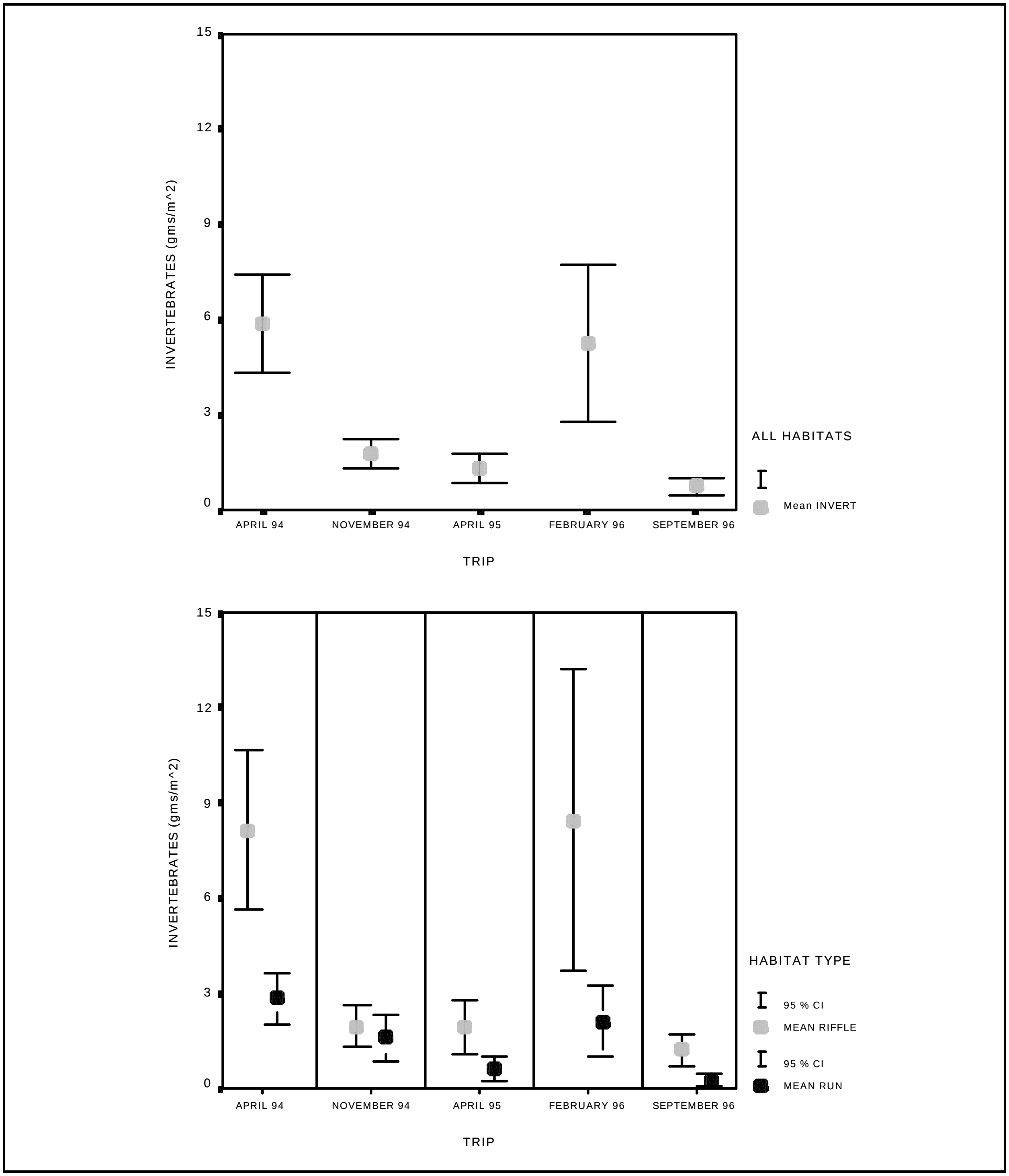

Figure 6.7 The Temporal Distribution of the Benthic Invertebrate Biomass (gm/m^2) for Each Trip Date for All Habitats Combined (above) and for Each Habitat Type (below) for the San Juan River

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Table 6.4 The comparison between pre- and post-runoff samples for each physical and biological parameter measured in the San Juan River.

Run Off Magnitude	Low (1996)	Medium (1994)	High (1995)
	RIFFLES		
Physical			
D_{16}	&	&	%
D_{50}	&	%	%
D_{84}	&	%	0
DTE	0	%	&
PAE	%	&	0
Biological			
Periphyton	0	&	&
Detritus	%	0	0
Invertebrates	&	&	%
	RUNS		
Physical			
D_{16}	&	&	&
D_{50}	&	&	%
D_{84}	&	&	%
DTE	%	%	&
PAE	%	&	%
Biological			
Periphyton	&	&	&
Detritus	%	0	&
Invertebrates	&	0	0

Trends: +=increase; 0=no change; - =decrease; + or - =significant P#.05

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Spatial Variations

In order to evaluate the spatial pattern exhibited by the parameters investigated in this study, mean values and confidence intervals (%=.05) were calculated by averaging the five sample dates. Reach 1 was only sampled once, but is included in this analysis. Significant differences for all habitats combined, as well as for riffles or runs, were initially determined by a one-way ANOVA followed by the Tukeys HSD which determined significant differences between specific reaches. All data was plotted by reach with mean values and 95% confidence intervals. Summary statistics are provided in Appendix C.

Physical Parameters

D_{50}, which estimates the size diameter of the median substrate, demonstrates significant differences by geomorphic reach both on a river-wide average and on a habitat specific basis (Figure 6.8). The river-wide lowest D_{50} values were found in Reach 1 (56 mm) and 3 (57 mm) with the largest median substrate in Reaches 6 (94 mm) and 8 (80 mm). On a river-wide basis, there appeared to be a decreasing trend with distance downstream, with the exception of Reach 2 which increased to 80 mm. Reach 2 is a canyon bound reach with steep gradient and large substrate associated with side canyon alluvial fans.

The comparison between habitat types also demonstrated significant differences between geomorphic reaches. Riffle habitats had significantly larger D_{50} values in six of the eight geomorphic reaches with its longitudinal pattern similar to the river-wide pattern. Runs were also similar to riffles in their distribution except for Reach 8, which decreased.

The percent surface area embedded (PAE) did not demonstrate any longitudinal pattern on a river-wide or habitat specific basis. Reaches 2, 5 and 8 had significantly lower PAEs compared to Reaches 3, 4, 6, and 7. On a habitat specific basis, riffles had significantly low PAEs in all eight geomorphic reaches (Figure 6.9) ranging from 7% to 29%. Runs were higher, ranging from 28% to 70%.

The depth to the embedded layer (DTE) plotted on a river-wide basis indicated that the most embedded geomorphic reaches were 3 and 8 (33 mm and 30 mm, respectively), while Reach 2 was the least embedded (85 mm). Comparisons made by habitat type indicated that only Reach 6 had a significant difference between DTEs in riffles and runs (Figure 6.10).

Biological Parameters

The spatial patterns observed in the biological components (periphyton, detritus, and macroinvertebrates) were very similar with the upper Reaches (6, 7, and 8) of the river being higher than the middle Reaches (3, 4, and 5). Reach 2 had the lowest concentration of organic materials.

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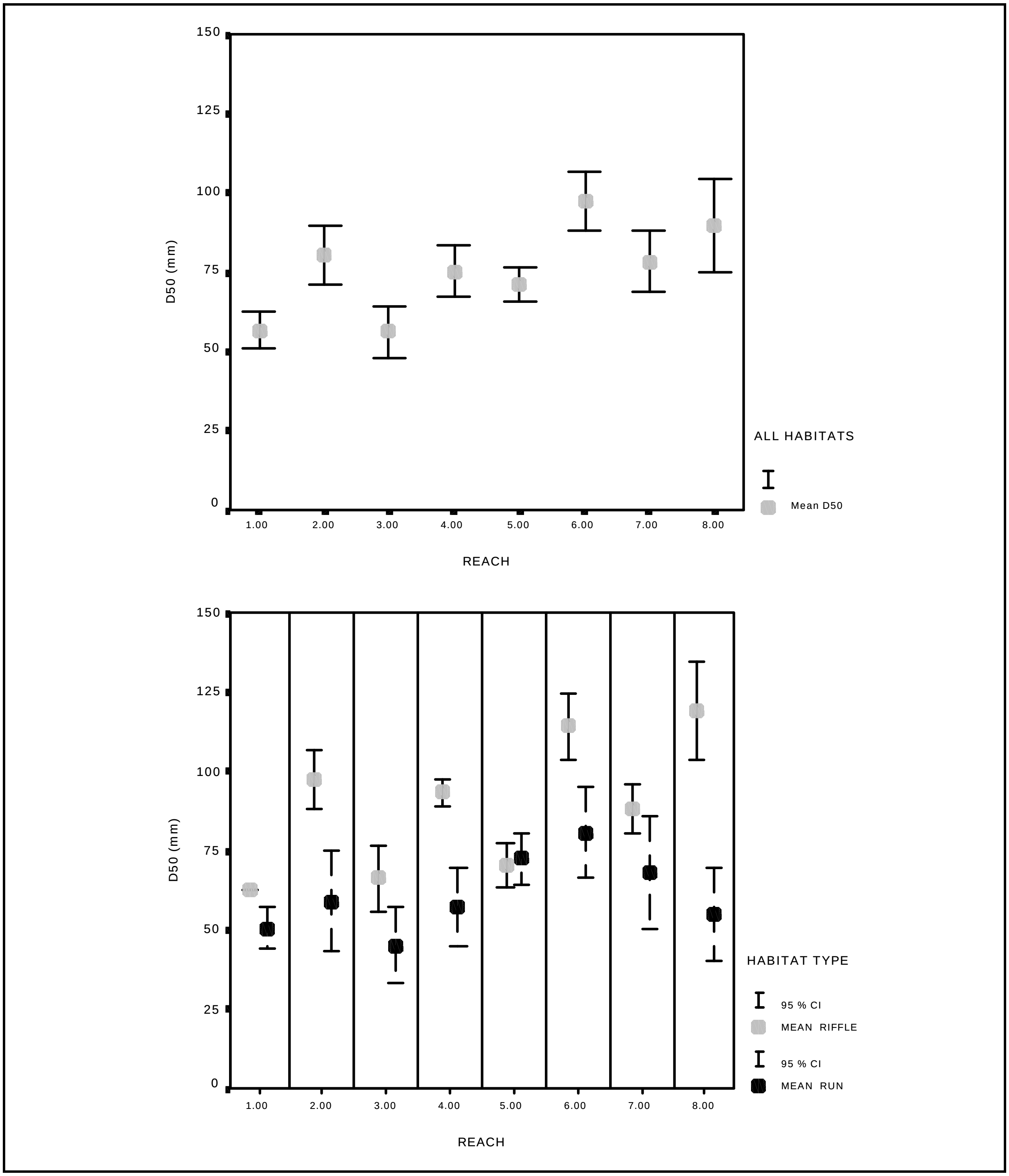

Figure 6.8 **The Spatial Distribution of the D_{50} for Each Trip Date for All Habitats Combined (above) and for Each Habitat Type (below) for the San Juan River**

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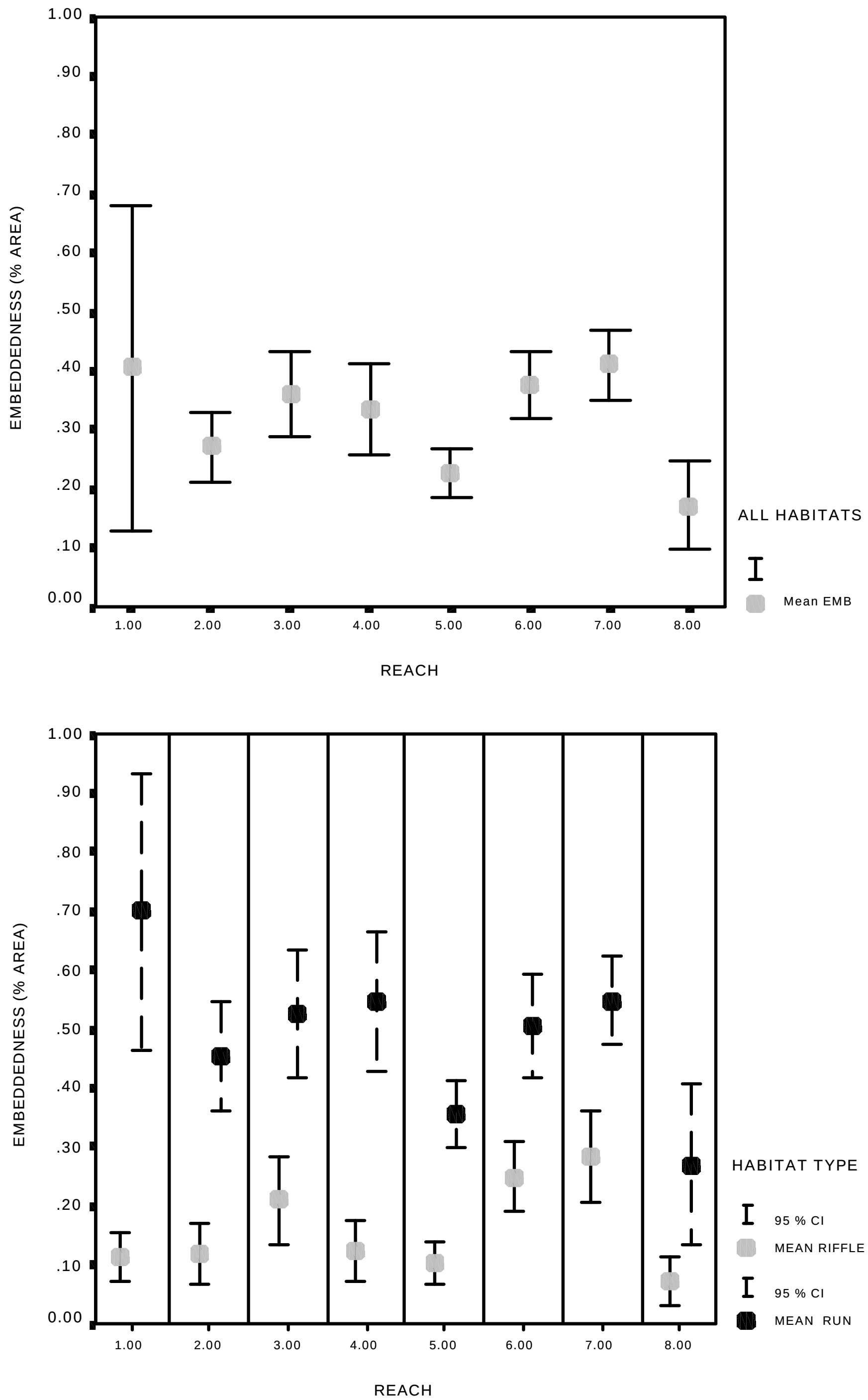

Figure 6.9. The Spatial Distribution of the Percent Surface Area Embedded for Each Trip Date for All Habitats Combined (above) and for Each Habitat Type (below) for the San Juan River

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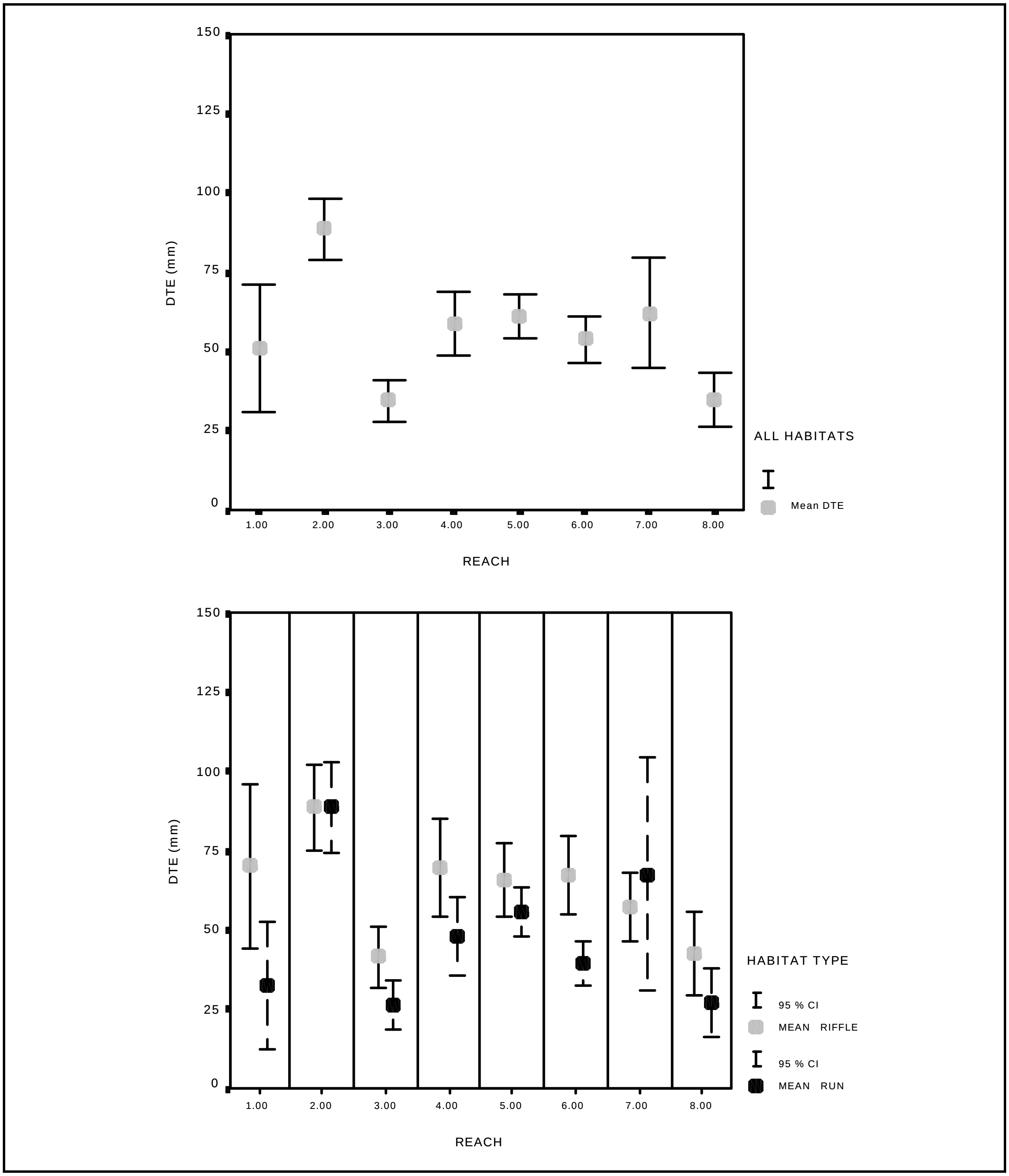

Figure 6.10 The Spatial Distribution of the Depth to Embedded Layer for Each Trip Date for All Habitats Combined (above) and for Each Habitat Type (below) for the San Juan River

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Periphyton biomass (Figure 6.11) peaked in Reach 6 and was lowest in Reach 2, both on a river-wide basis as well as a habitat specific basis. It is interesting to note that there were no significant differences between riffles and runs in any geomorphic reach in the San Juan River.

Benthic detritus demonstrates a strong longitudinal pattern with the lowest biomass in Reach 2 (38 gm/m^2) which steadily increased with distance upstream, reaching its highest river-wide average in Reach 8 (92 gm/m^2). The comparison between habitats (Figure 6.12) indicated that riffles contained significantly greater detrital biomass in five of the eight reaches. For both habitats, the same longitudinal pattern was evident.

The longitudinal pattern for benthic macroinvertebrates can be seen in Figure 6.13. As in the spatial pattern observed in detritus, invertebrates also increased with distance upstream in both a river-wide and habitat specific manner. Lowest densities (0.40 gm/m^2) were found in Reach 2 and the highest densities (12.4 gm/m^2) in Reach 8. A comparison by habitat types indicated that five of the eight reaches had significantly greater invertebrate biomass in riffles compared to run habitats. The greatest differences between habitats occurred in Reaches 6, 7, and 8 within the San Juan River.

DISCUSSION

A similar survey of abiotic and biotic parameters was undertaken on the Colorado River during 1994 and 1995 (Lamarra 1999) utilizing the same protocols. In the case of the Colorado River, eleven geomorphically similar reaches were sampled compared to the eight in the San Juan River. The Colorado River also exhibited vastly different gradients compared to the relatively constant gradient of the San Juan River (Figure 3.1).

Comparisons of the physical and biological parameters can be seen in Figure 6.14 for both rivers on a river-wide average (riffles plus runs) by geomorphic reach. The data are averages over all sample periods.

The physical data (D_{50}, depth to embedded layer, and percent surface area embedded) demonstrates that the ranges of data encountered within the two river systems are similar. The D_{50} values in the San Juan River have less variability river-wide than do the D_{50} values in the Colorado. However, comparing areas of similar gradient (all of the San Juan vs. Reaches 7, 8, and 9 of the Colorado) resulted in similar D_{50} values and variabilities.

The biological data between the two rivers was very similar both in spatial distribution and magnitude. The exception was periphyton biomass (expressed as chlorophyll-*a*). The biomass of chlorophyll-*a* was two to four times greater in the San Juan River. This may be a reflection of the more turbid environment in the San Juan River and the associated low light adaption of increased chlorophyll levels. Steemann-Nielson and Jorgenson (1968) and Jorgenson (1969) found that algal cells of green algae adapted to high light intensity by lowering their chlorophyll-*a* content per cell, while those algae in low light had ten times more chlorophyll per cell. The actual rate of photosynthesis was not much greater in the high light climate compared to the low light climate.

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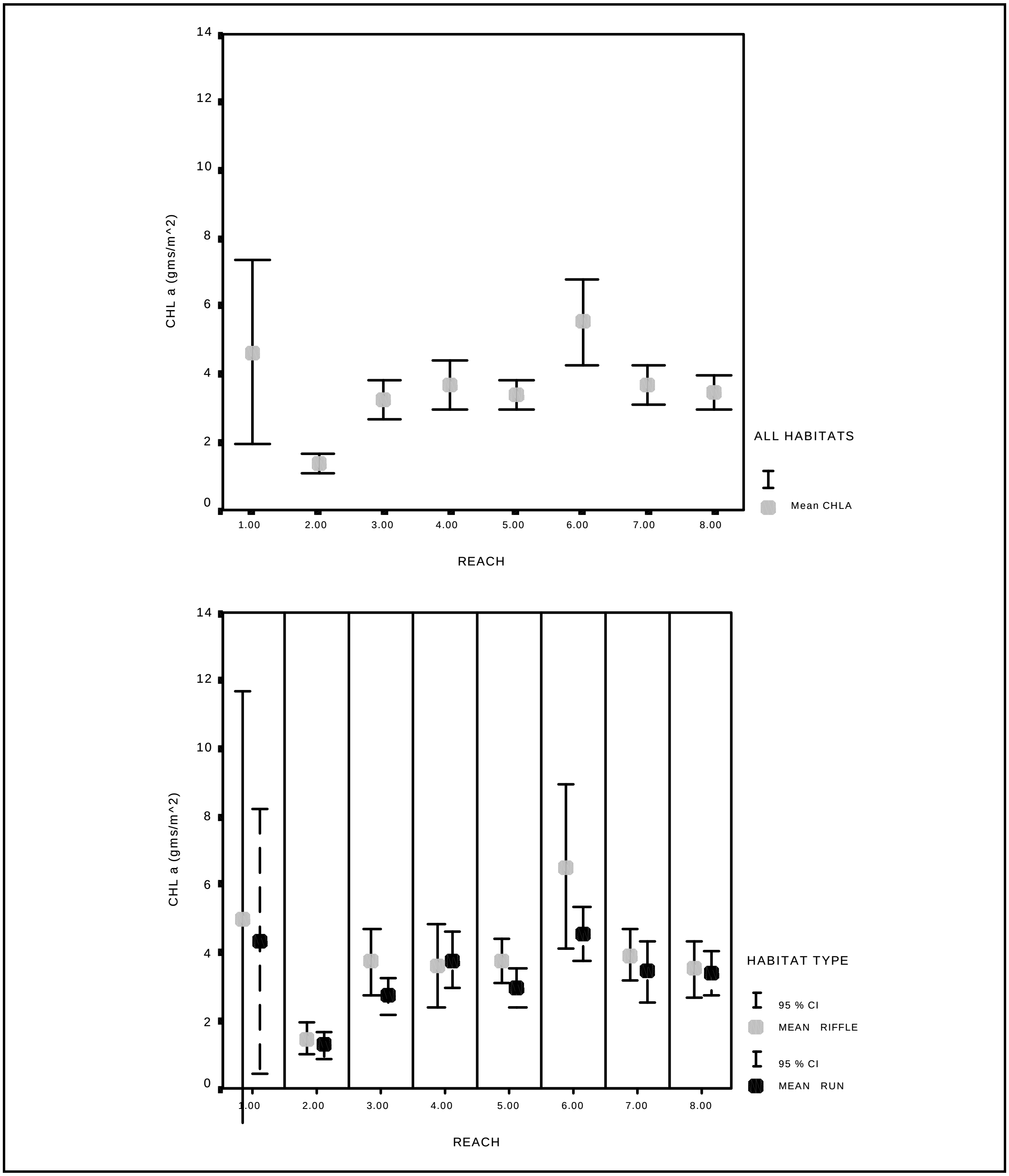

Figure 6.11 The Spatial Distribution of Periphyton Biomass (gms chla/m^2) for Each Trip Date for All Habitats Combined (above) and for Each Habitat Type (below) for the San Juan River

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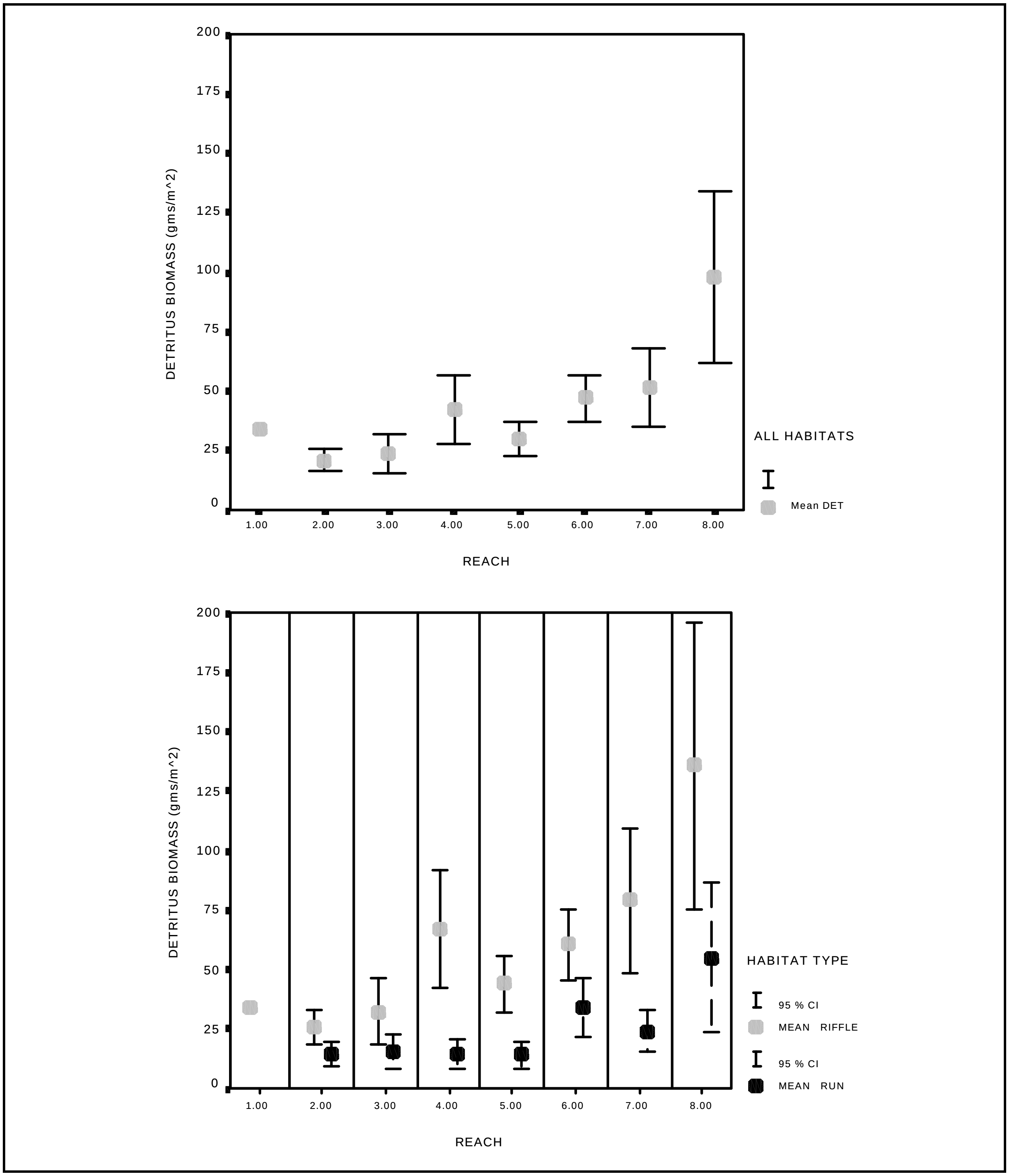

Figure 6.12 **The Spatial Distribution of Benthic Detritus (gm/m^2) for Each Trip Date for All Habitats Combined (above) and for Each Habitat Type (below) for the San Juan River**

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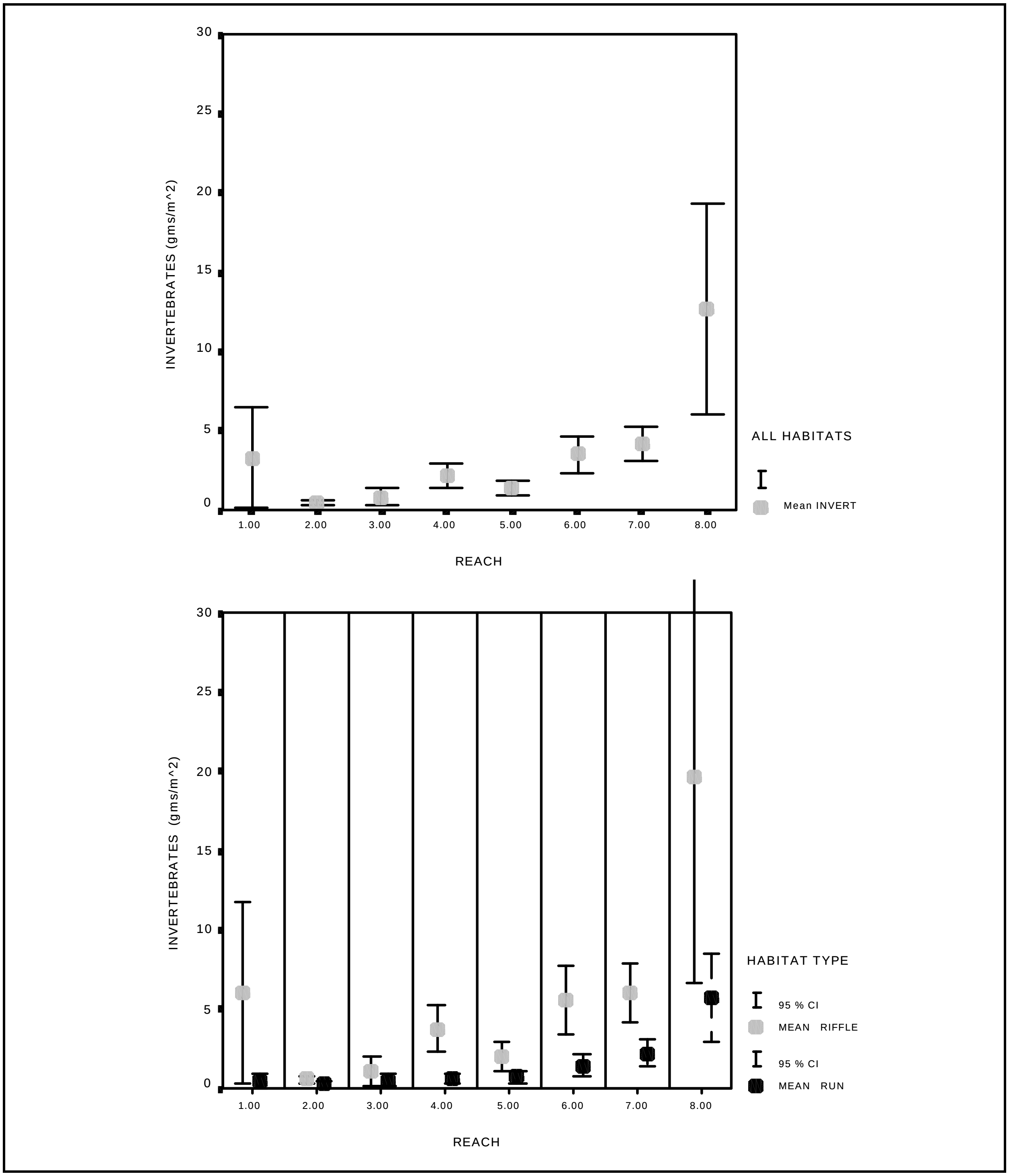

Figure 6.13 **The Spatial Distribution of Benthic Invertebrates (gm/m^2) for Each Trip Date for All Habitats Combined (above) and for Each Habitat Type (below) for the San Juan River**

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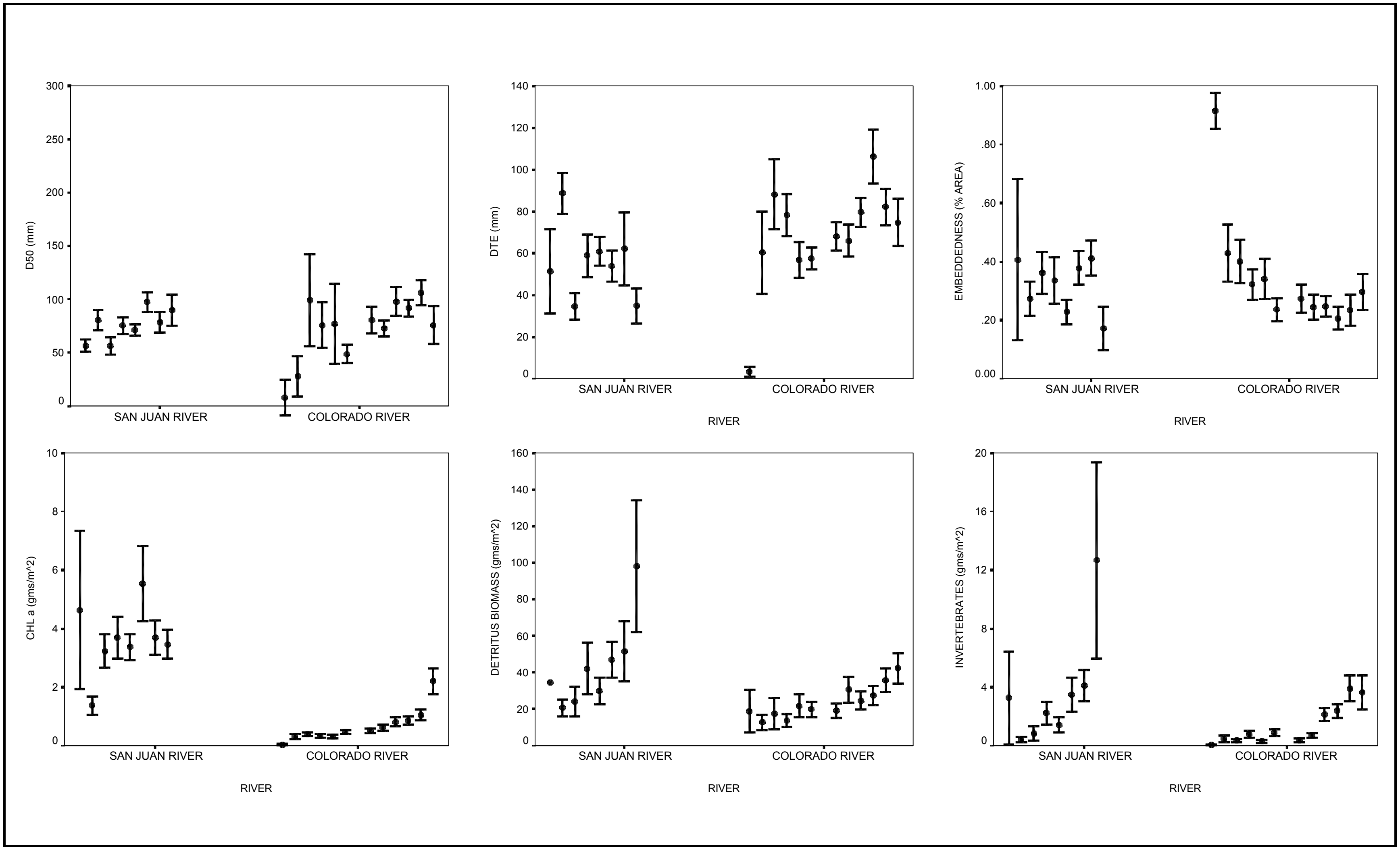

Figure 6.14 The comparison for physical (above) and biological (lower) trophic parameters collected on the San Juan and Colorado River during 1994, 1995, and 1996. Within each river, the lowest geomorphic reach is on the left, with movement upstream toward the right. The San Juan has eight reaches, while the Colorado has eleven.

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Detritus and invertebrates were slightly higher in the San Juan but overlapped with most Colorado River reaches (especially Reaches 7, 8, and 9) where river gradients are similar to the San Juan River.

Figure 6.15 provides an overall summary of the data collected on the San Juan and Colorado rivers by habitat type. These data are averages and 95% confidence intervals for all dates (1994-1996) and all river reaches by habitat type. It is interesting to note that for all parameters, the two rivers had identical patterns when comparing riffles to runs. In both rivers, riffles had higher D_{50}, DTE, periphyton, detritus, and invertebrates while runs had higher percent embedded surface areas. A comparison between the rivers indicated that D_{50} and percent embedded surface areas did not differ for either habitat between rivers. The DTEs in riffles was, however, significantly greater in the Colorado (95 mm) compared to the San Juan (60 mm) while runs remained the same. Periphyton and invertebrates were significantly greater in the San Juan for both habitat types while detritus was significantly greater only in riffle habitats. It should be noted that although both data sets cover approximately 200 river miles, the Colorado data include areas of lower gradient and lower productivity. This is reflected in the lower overall biomass of the biological parameters.

SUMMARY AND CONCLUSIONS

Riffle and run habitat types were sampled for abiotic and biotic parameters before and after spring runoff for the years 1994, 1995 and 1996. The physical parameters (depth to embedded layer, D_{50}, and percent surface area embedded) were significantly different between riffles and runs. Biological parameters (periphyton, detritus and invertebrates) were not different between habitat types. The comparison of sample locations (geomorphic reach) by habitat types for the abiotic and biotic parameters indicated significant longitudinal differences for periphyton, detritus and invertebrates with upper geomorphic reaches having higher densities (greater biomass) than lower reaches. The comparison between the lower 200 miles of the Colorado with the San Juan study area indicated similar characteristics in abiotic conditions and similar biomass levels for biological components.

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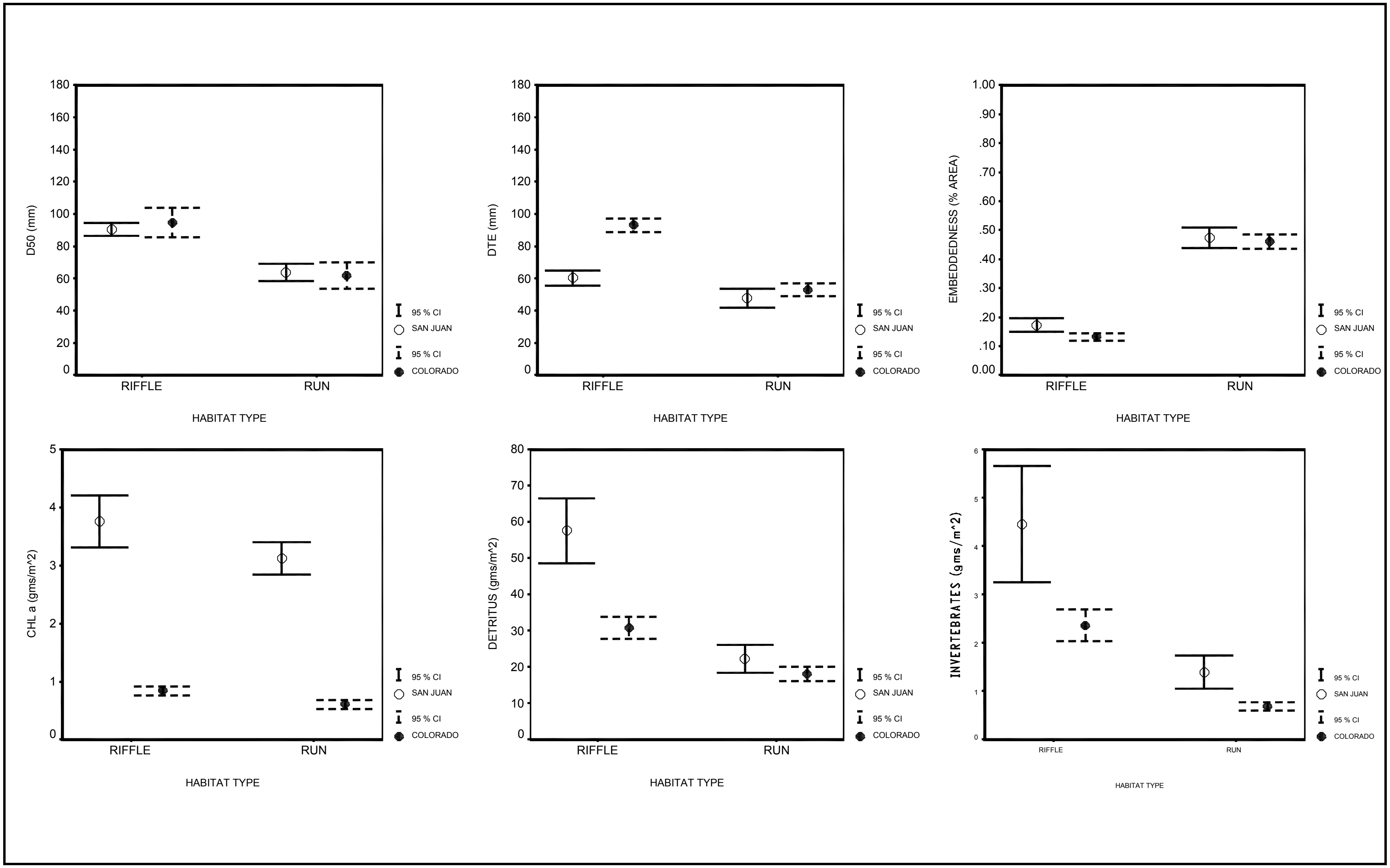

Figure 6.15 the Overall Averages of Physical (above) and Biological (lower) Benthic Parameters Collected in Riffles and Runs in the San Juan and Colorado Rivers

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